THE INFLUENCE OF LIGHT INTENSITY ON OVIPOSITION OF THE COTURNIX QUAIL

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Interest in the Japanese Quail (*Coturnix coturnix japonica*) as an avian laboratory species has been spreading rapidly. Because of the increasing need for birds and eggs for study, there is much work being done on factors affecting egg laying by the quail. One of the major influences is light (see Abplanalp, 1961; Reese and Reese, 1962; Wilson et al., 1962). As with other birds, notably chickens and ducks, most of these studies have involved the role of photoperiodism with respect to egg laying. We have been more interested in the effects of light intensity as such on the egg laying patterns of the quail. Where other studies have shown a definite correlation between photoperiodism and egg laying (Abplanalp et al., 1962; Abplanalp, 1961), this study shows that time and place of oviposition are influenced by the available light intensity.

MATERIALS AND METHODS

Cages 142 cm (56 inches) by 55 cm (22 inches) by 30 cm (12 inches) deep of one-inch wire mesh were set up as shown in Figure 1. A variety of light sources was employed, one at a time, including a fifty watt light bulb, a fifty watt bulb heavily filtered with colored cellophane, and a ten watt bulb. The ten watt source placed in one end of the cage gave a light gradient along the cage length ranging from forty foot-candles near the source to less than one-half foot-candle at the opposite cage end. Intensities were measured as incident light.

The cages were blocked from extraneous light by heavy, dull, black plasticized cloth. The cage bottoms of one-inch wire mesh effectively prevented rolling and kicking about of the eggs after they were laid. Food and water positions were changed frequently in relation to one another and the light source to eliminate their placement as a factor in position of egg laying, and to avoid a training effect, as discussed below.

There were approximately twenty birds to a cage, of which 25 per cent were males. Ten to twelve eggs were collected daily. Food was commercial Purina game bird chow. Lights were kept on in the cages continuously. Room temperature was fairly constant at 22 degrees centigrade.

RESULTS

We first used incandescent white light sources, in an attempt to ascertain the precise intensities in which laying tended to occur. The results are summarized in Figure 2. A large proportion of the eggs (60.8%) were laid be-

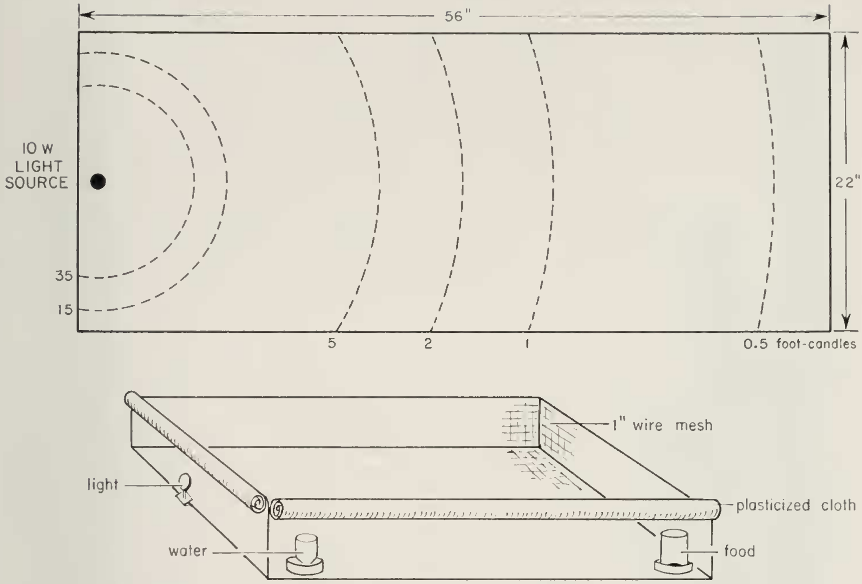


Fig. 1. Floor-plan and a three-dimensional sketch of the cage setup used. Dotted lines in top figure indicate light intensities at various cage positions. Note light, food, and water, shown in a typical arrangement.

tween two and 0.5 foot-candles intensity. Seventy per cent of the eggs in this range (or, 55.3% of the total eggs) were placed in light intensities between one and 0.5 foot-candles. This latter range of 0.5 foot-candles could be resolved no further due to limitations on the photometer employed in these determinations, and practical limitations involving the precise positioning of the eggs when dropped on the one-inch mesh floor.

It should perhaps be noted that precisely one egg was gathered per day in the higher light intensity ranges. This fact tends to indicate that the same bird was doing the abberant laying in all cases; perhaps this bird had some malfunction (blindness) which caused her to lay her eggs in response to some other stimulus (for example, heat). This assumption has not been verified.

One light source used was a fifty-watt incandescent bulb, which put out enough light so that the intensity even at the opposite end of the cage was greater than the two-foot-candle maximum of the preferred laying range. The food container was placed precisely in the middle of the cage; hence, it cast a shadow, and this shadow was the only cage area in which the light intensity was less than two foot-candles. Consequently, ninety per cent of the eggs laid under these conditions were laid in the shadow of the food can. When the

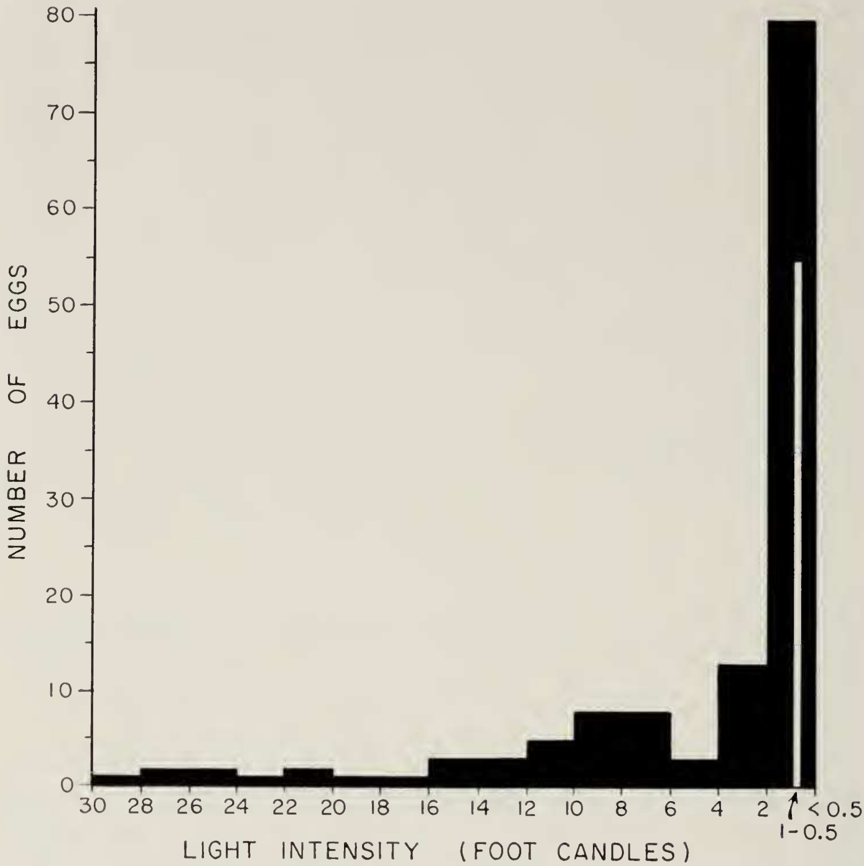


Fig. 2. Number of eggs collected versus collection intensities for white light. Note majority of eggs laid at less than two foot-candles, and most of these between one and 0.5 foot-candles.

food can was moved against the rear of the cage, so that it cast no shadow, the eggs were still deposited precisely where they had been before—that is, where the food-can shadow had been, but where there was now an increased light intensity (ranging from four to twenty foot-candles). This training effect continued for about one week, during which time progressively fewer eggs were laid daily in the higher intensity area, and more were laid at the very rear of the cage. These results are summarized in Figure 3, which is a plot of number of eggs collected versus light intensity for the first week after the food container was moved. A greater number of eggs was laid in the higher light intensities than under normal conditions (Fig. 2).

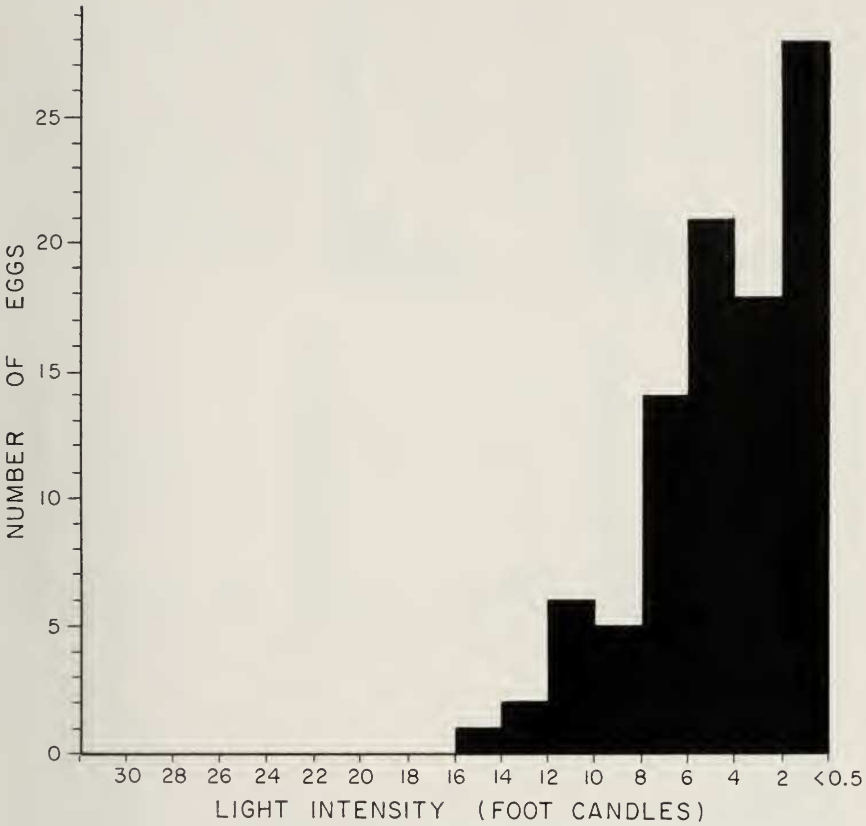
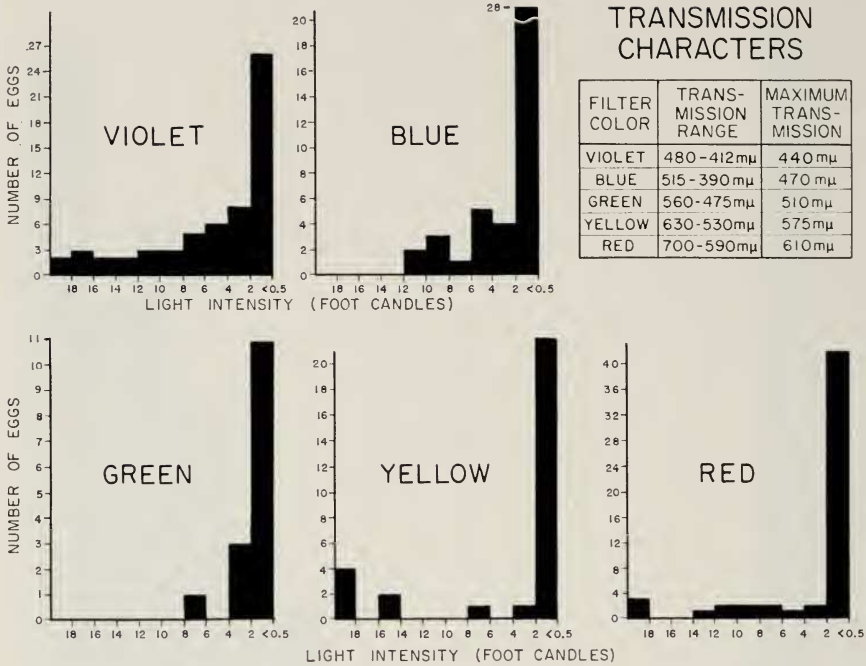


Fig. 3. Demonstration of "training effect," as explained in text. Plot of number of eggs versus light intensities, for first week after low intensity shadow eliminated from cage. Higher intensities shown here found where shadow had been.

Having attained these results with a white light, similar studies were made using colored lights to ascertain whether the egg laying response was initiated by light of a particular wavelength, rather than by the sum of wavelengths given by a white light. Using the same experimental setup as before, but with colored cellophane filters over the light source, essentially the same results were obtained as for the white light. These results are summarized in Figure 4.

The colored filters cut down the light intensities to a considerable extent: the cages were, in fact, quite dark throughout. Consequently, egg production dropped off markedly, and after several weeks essentially no eggs were being laid. These results agree with those of Abplanap (1961). The eggs which were gathered during this period were small, sterile, and had extremely thin



TRANSMISSION CHARACTERS

FILTER COLOR	TRANS-MISSION RANGE	MAXIMUM TRANS-MISSION
VIOLET	480-412mμ	440mμ
BLUE	515-390mμ	470mμ
GREEN	560-475mμ	510mμ
YELLOW	630-530mμ	575mμ
RED	700-590mμ	610mμ

Fig. 4. Number of eggs collected versus light intensities for various colored light sources. Note similarity, in all cases, to Fig. 2.

shells. The effects of darkness on *Coturnix* are well known and have been described (Abplanalp, 1961; Abplanalp et al., 1962; Wilson et al., 1962). After being subjected to the original light intensity for one week, egg production was back to normal. Reinitiation of egg laying was thus easily accomplished in *Coturnix* although this is not so easily done with some other birds (Farner, 1964).

The darkness effects were least pronounced with red light; egg production in red light continued normally for almost one month. This may be because red light penetrates organic tissue best, and thus a lower intensity of red light will elicit the same response as a higher intensity light of another color (Farner, 1964), or perhaps the visual "oil filters" responsible for color vision in birds (Wald, 1950) differ slightly. If the red droplets were either in less abundance than yellow or red-green droplets, allowing more red light to reach the actual photoreceptors of the cones, or were more readily penetrable than the other two, a greater visual response for a given light intensity would be elicited. It should be noted, however, that two conflicting responses were observed, in that egg laying continued for a longer time in the red light, indi-

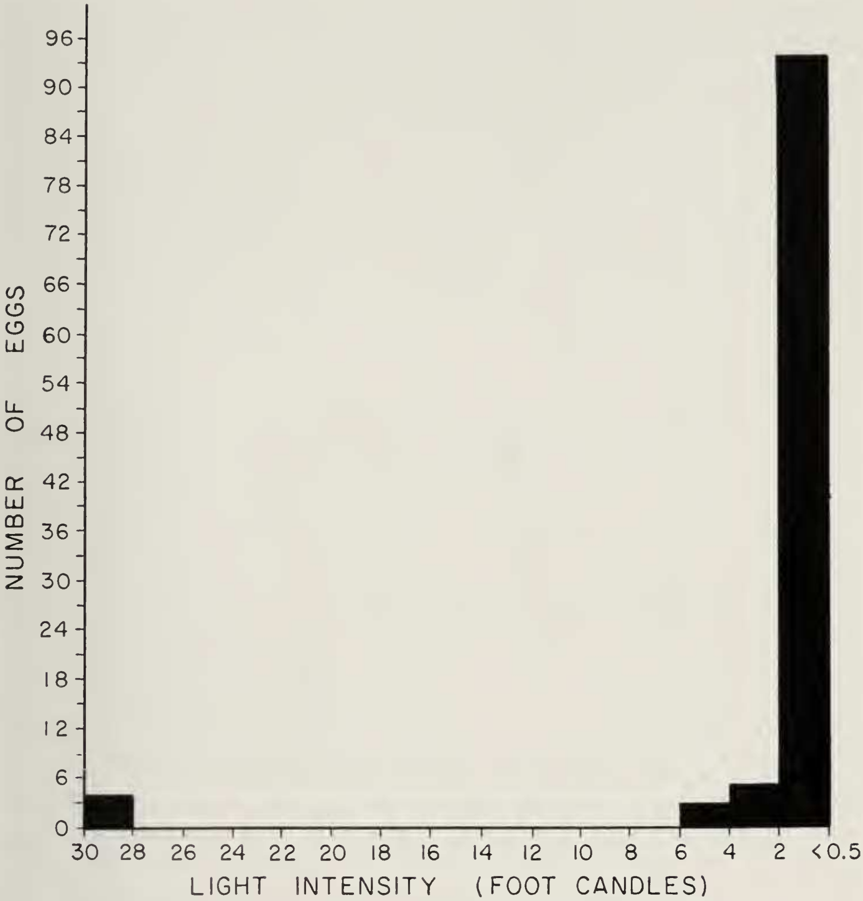


Fig. 5. Number of eggs collected versus light intensities from cage having heat filter placed to eliminate differential temperature effects on oviposition.

cating greater sensitivity to long wavelengths, yet eggs were placed in the same light intensities in which they were placed with all other light sources.

According to Wald (1950), there are droplets in the visual cones of birds corresponding to each of the three primary colors, and a fourth type, which is essentially clear. Thus a part of white light is able to penetrate all droplets, and the response elicited by a given white light would naturally be greater than that from a colored light of comparable intensity. Thus laying is most readily maintained in white light.

At this point in the experiments, it was impossible to ascertain with certainty whether the observed response was the result of a light or of a temperature gradient. Whereas a light gradient was indeed observable, the incandescent light source also produced a partial temperature gradient through the cage length, which may have been the cause of the observed egg distribution, rather than the variations of light intensity within the cage.

Temperature and light as factors were effectively separated by the use of a heat filter consisting of two sheets of one-fourth inch thick plate glass, mounted two inches apart in a wooden frame. Using this device in front of the light source, a temperature difference of no greater than 0.5 degrees centigrade was ever observed in simultaneous readings over the cage length. Under conditions with a light gradient but constant temperature, oviposition occurred in the 2—0.5 foot-candle range in 88.7 per cent of all cases. These results are shown in Figure 5.

In these determinations, the small, ten-watt bulb was used. Because of reflection and absorption by the glass filters, the maximum light intensity within the cage was decreased from 40 to 34 foot-candles with this light source. The effect on the minimum intensity within the cage could not be determined due to equipment limitations. The result of the lowered intensity, however, was that the 2-0.5 foot-candle range occupied 70 per cent of the cage length, or 20 per cent more than previously. Egg distribution within the 1—0.5 foot-candle range was more easily observable in the increased area covered thereby; assortment was found to be random within that range.

During this period, several of the female quails were becoming blind. The eyes of these birds were observed to be swelling shut. As this blindness progressed, more and more eggs were laid in the higher light intensities.

During a period of one week, the individuals used in these experiments were subjected to sixteen hours of high intensity light, which was, however, constant over the entire cage length. During the other eight hours of the day, the birds were subjected to the usual light gradient. All eggs were laid during the eight hours of relative darkness, apparently, as they were gathered in the same pattern as before. These results substantiate the premise that long-period high intensity light may inhibit the actual laying response (Farner, 1964).

DISCUSSION

Egg laying in low light intensities may confer several adaptive advantages on the quail. These intensities correspond to the very early dawn hours, at which time the air and ground temperatures are still relatively low. Thus the eggs will be rapidly cooled upon laying. This cooling has been found to be necessary before development of the embryo can proceed (Padgett and Ivey, 1964).

The light at dawn (and dusk) tends to be shifted toward the red end of the spectrum in comparison with the light during the rest of the day, due to refraction of the sunlight by a greater depth of atmosphere. As explained previously, the egg laying response is easily elicited by red light. Thus the propensity to lay eggs in low light intensities is reinforced by the fact that said light intensities tend to be "red" when found in the birds' natural environment.

When the results here described are considered along with the work of others on the effects of light on the reproductive behavior of *Coturnix* quail, it becomes apparent that both light intensity and photoperiodism are important in the integrated response observed. Wilson et al. (1962) have made studies indicating that rate of sexual maturation is independent of light intensity. The same paper indicates the importance of day length on reproductive maturation, with photoperiods of fourteen or more hours being required for quantity egg production. This mechanism results in the production of eggs primarily in the long days of spring, when other factors such as food supply and temperature are optimal. An even longer photoperiod, such as that found in later months (June, July) may result in a dropping off of egg production (Farner, 1964). This lowering of egg production was not observed in the white light experiments here presented, even though lights were on in the cages continuously. This may have been due to the exceedingly low light intensities in which the birds spent part of their time. As a bird moved from the rear of the cage (farthest from the light—low intensity) to the front of the cage (near the light—high intensity) and back again, it may be considered to have undergone a brief high intensity light exposure. Because light intensities greater than 0.5 foot-candles were found over a much larger cage area than were low intensities (less than 0.5 foot-candles), and because movement of the birds was random throughout the cages, it can be considered that each bird was regularly subjected to a high-intensity exposure of greater than twelve hours per twenty-four hour day.

Farner (1964) has described a "pre-reproductive preparatory period" which he has observed in birds. This consists of a high-intensity, relatively long photoperiod, such as a spring day, which is actually responsible for maturation of the reproductive system in preparation for copulation and egg laying. Egg laying can then occur at a later time when conditions for it, in turn, are optimal. The high intensities of light available in our experimental setup fulfill this preparatory function. The odd effects observed in the red light may be due in part to this light color precipitating reproductive maturation more readily.

Abplanalp (1961) has also done studies involving pre-conditioning, which indicate that a period of darkness prevents egg production during its application but enhances the later response of the hens to light. On the other hand, he indicates that intermittent lighting has an adverse effect on egg production. Both of these conditions were present in the white light setups employed by us (as explained above) yet egg production remained high. The effect of darkness apparently outweighs the intermittent lighting effects on subsequent egg laying.

The hens' inherent physiological tendency to ovulate once every twenty-four hours was not interrupted by the setup employed, as laying remained high and steady (during the first series of white light experiments). Such interruptions are, however, common under conditions of simple unnatural day lengths (Abplanap, 1962).

Wilson and Huang (1962) indicate that, in the studies they have made, about eighty per cent of *Coturnix*' eggs were laid in the afternoon. However, it should be noted that the attendants were in the area during the early morning hours when egg laying would normally take place, quite possibly frightening the birds enough to delay oviposition. Arrington (1962) concurs with this afternoon-laying observation. More work is needed on this subject, as conflicting observations are apparent (Arrington et al., 1962; Wilson and Huang, 1962; Abplanalp, 1961).

SUMMARY

Coturnix quail has been found to lay its eggs in low light intensities when a range of intensities is available. The intensities at which laying took place were found to be independent of light color, although other responses were modified in monochromatic lights. The experimental setup used allowed for both development of the reproductive systems of males and females and the finalization of this maturation, namely, the laying of fertile eggs. The response to the influences of light intensity is apparently evolutionarily significant, in that several advantages are therewith conferred upon the species. Results employing heat filters to eliminate temperature differences over the cage length indicate that temperature gradients play essentially no role in these results.

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